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Technical Efficiency of Early Variety Country Bean Cultivation in Selected Areas of Bangladesh: A Stochastic Frontier Approach

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ABSTRACT

The present study was undertaken to measure profitability and technical efficiency of early variety country bean cultivation in selected areas of Chatmohar upazila of Pabna district. A total of 60 early variety country bean growing farmers were selected from three villages of Chatmohar upazila using simple random sampling technique. Stochastic frontier production function was applied to determine the technical efficiency of the country bean growers. Technical inefficiency effects model was also applied to identify the demographic and socio-economic factors by which inefficiency effects are influenced. The study revealed that Benefit Cost Ratio (BCR) was the highest (2.29) for large farmers followed by medium (2.27) and small farmers (2.21). The result of the Maximum Likelihood Estimates (MLE) showed that human labor, fencing and manure had significant positive impact whereas the irrigation and insecticides had negative impact on the production of country bean. The results of technical inefficiency effect model showed that farmer's age, farm size had negative impact while education, family size and farm credit had positive impact on technical efficiency. The inefficiency analysis results indicated that farm level technical efficiency ranged between 43.06% and 98.01% with a mean technical efficiency of 91.9% implied that there was potential to increase country bean production among smallholder farmers in the study area by 8.1% through efficient use of present technology. The main constraints to country bean (early variety) production were identified as- infestation of pest and disease, high price of inputs, paucity of quality seed and fertilizer, scarcity of human labor, lack of technical knowledge, limited access to institutional credit etc. Despite the constraints, there is a great prospect of early variety country bean production in the study areas. Country bean (early variety) production could be increased in a sustainable manner if farmers would be provided with government support regarding lower price of input, fair price of output, marketing facilities, training for farmers and farm credit at low interest rate, reducing the activities of syndicate of middlemen. Government should provide necessary support to the farmers for ensuring sustainable production of early variety country bean.

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INTRODUCTION

Country bean (*Lablab purpureus* L.) is one of the popular winter vegetables in Bangladesh. It belongs to the sub-family Papilionaceae under the family Leguminosae. Internationally the crop is known by various other names such as hyacinth bean, field bean, lablab bean, banner bean, pig-ears, poor man's bean, tonga bean, seim bean, Dolichos bean or Indian bean (Verdcourt, 1970; Zeven and De Wet, 1982). Country Bean is a short-lived creeping perennial but cultivated as an annual legume. It is used in different ways. Green pods are cooked as vegetable while dry seeds are eaten directly by frying or cooking and also used in various preparations.

Among vegetables, the bean is one of the most important leguminous vegetables in Bangladesh and is normally grown during the Rabi or winter season. It is not only highly productive but also nutritious crop. Beans are delicious and can enrich soil fertility. Beans contain calories 131.98 (k cal/100g), carbohydrates 23.72g, protein 8.84g, fat 0.52g, vitamins 6.86 mg, mineral 596.99 mg, water 65.7 g per 100 g of beans (USDA, 2012). The beans have the lowest content in fats, oils and sugars. They are the perfect food for a fat-restricted diet. It contains no cholesterol and they can help lower the cholesterol level because they are one of the richest sources of fiber (Taslim et al., 2021). It has anti-diabetic, antifungal, anti-inflammatory, antioxidant, analgesic, hypolipidemic, cytotoxic, antimicrobial, hepatoprotective, insecticidal, antispasmodic, and anti-lithiatic effects shown in pharmacological studies of bean (Singh and Sankar, 2012). Gradually bean production in Bangladesh has been increasing over the years. The production of bean has risen from 110 Thousand MT in 2013 to 170 Thousand MT in 2021(BBS, 2021). It is widely known as "S*heem*" in Bangladesh which mainly grown in the winter (Rabi) season and also in summer season (Kharif) more recently (Biswas, 2015).

Country bean of early variety is an important and promising vegetable crop grown in Bangladesh that fits well in the cropping pattern. With the invent of modern agricultural technology and research efforts, early variety country bean has become an emerging vegetable in Bangladesh due to its higher nutritional value, yield potential, off season availability in the country and a strong market demand. The early variety country bean cultivation has gained popularity among the farmers in Pabna district and one kind of revolution occurred in these areas leading to a vast acreage covered by it. Due to its availability in the off season, the higher demand and market price leads the farmers come forward to grow this important vegetable crop for its higher financial returns. A large number of farmers in Pabna district are now engaged in early variety country bean cultivation as profitable farming. The cultivation of country bean can generate employment opportunity for the rural people in Bangladesh. Bean production has increased but it comprises only 1.16% of total vegetable production in the country (BBS, 2021). There is an ample scope to increase both the areas and production of this important vegetable crop in the country. The country bean (early variety) has a great potential in international market. Traditionally country bean has been regarded as a subsistence crop for low-income farm households. Recently the view of country bean as simply a subsistence crop has begun to change and there is growing interest in developing its commercial farming through increased acreage, increased productivity, harvesting and marketing facilities. Country bean production is gaining continuous popularity and recognition by the village farm households and impacting gradually in the increased production of crops and socioeconomic upliftment of the producers. Several research studies conducted and mainly (Rahman et al., 2022; Alam et al., 2018; Hasan et al., 2014; Hayat et al., 2015; Taslim et al., 2021) focused on constraints to bean cultivation and profitability and the study results found that bean cultivation was profitable. No such empirical study was conducted on the technical efficiency of early variety country bean cultivation focusing inefficiency effect model, the present study therefore, was undertaken for measuring profitability and technical efficiency of early variety country bean production with the following specific objectives:

- To know the socioeconomic characteristics of farmers producing early variety country bean;
- To estimate the profitability and technical efficiency of early variety country bean and
- To identify the constraints faced by the farmers producing country bean in the study areas.

MATERIALS AND METHODS

Study areas, sample, sampling technique and data collection

Chatmohar upazila of Pabna district was selected purposively for the study as it is an important area where early variety country bean is grown intensively. Three villages namely- Kamalpur, Koyrapara and Charil of Chatmohar upazila were selected for conducting the study. A list of country bean growers was prepared with the help of DAE (Department of Agricultural Extension) officials and from the list a total of 60 country bean growers were chosen randomly taking 20

farmers from each of the three selected villages. Data were used in the study for 2017-18 crop season and required data were collected employing direct farm survey method with the help of pre-designed and pre-tested interview schedule. Both tabular and statistical techniques were used to analyze the data.

Analytical technique

Benefit-Cost Ratio (BCR)
Benefit-cost ratio is the ratio of present net worth of benefit and present net worth of cost. It indicates that the benefit of per unit cost at present worth (Dillon and Hardaker,1993).

Benefit-Cost Ratio =	$\frac{\text{Present net worth of benefits}}{\text{Present net worth of cost}}$

Technical efficiency analysis

The stochastic frontier model was used to estimate the technical efficiency because stochastic frontier model is considered more appropriate than DEA (Data Envelopment Analysis) in agricultural applications especially in developing countries, where the data are likely to be heavily influenced by the measurement errors and the effects of weather conditions, diseases, etc. (Coelli et. al. 1998).
The technical efficiency of the i-th sample farm, denoted by TE; is given by:

$TE_i = exp\ (-Ui) = Yi / f(X_i\ \beta)\ exp(V_i) = Y_i/Y_i^*$..... .... (1)

Where $Y_i^* = f(X_1\ \beta,)\ \exp(V_i)$ is the farm specific stochastic frontier. If Y_i is equal to Y_i^* then $TE_i = 1$, reflects 100% efficiency. The difference between Yi, and Y_i^* is embedded in U_i,
If $U_i = 0$, implying that production lies on the stochastic frontier, the farm obtains its maximum attainable output given its level of input. If $U_i < 0$, production lies below the frontier- an indication of inefficiency.

The maximum likelihood estimate (MLE) of the parameters of the model and the generation of farm-specific TE defined by (1) are estimated using the FRONTIER 4.1 package (Coelli, 1994). The efficiencies are estimated using a predictor that is based on the conditional expectation of exp (-*U*) (Battese and Coelli, 1993; Coelli, 1994). In the process, the variance parameters σ^2_u, and σ^2_v, are expressed in terms of the parameterization:

$\sigma^2 = (\sigma^2_u + \sigma^2_v)$ .... (2)
and
$\gamma = (\sigma^2_u / \sigma^2)$ .... (3)

The value of γ ranges from 0 to 1 with values close to 1 indicating that random component of the inefficiency effects makes a significant contribution to the analysis of the production system (Coelli and Battese, 1996).

Empirical Cobb-Douglas frontier production function model

The stochastic production function for the sampled farmers was specified as:

$\ln Y = \beta_o + \beta_l \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 1n X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + V_i - U_i$ (4)

Where, Ln = Natural logarithm, Y = Observed farm output (kg/ha), X_1 =Human lab or (man-days/ha), X_2 = Seed (kg/ha), X_3 = Insecticide/pesticide (kg/ha), X_4 = Irrigation cost (Tk./ha), X_5 = DAP cost (Tk./ha), X_6 =TSP cost (Tk./ha), X_7 = MoP cost (Tk./ha), X_8 = Manure cost (Tk./ha), X_9 = Fencing and stage cost (Tk./ha), X_{10} =Cable cost (Tk./ha), β_i = Unknown parameters to be estimated, V_i = Random Error terms, U_i = Inefficiency effects

Technical inefficiency effect model

The technical inefficiency effects U_i's in eq (4) are defined as

$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + W_i$ .... (5)

Where, Z_1 = Family size, Z_2 = Farm size, Z_3 = Age, Z_4 = Education, Z_5 = Credit (Dummy:1 if taken; 0=otherwise), δ_i = Parameters of the respective technical inefficiency variable to be estimated (i=l, 2,...5), W_i =Unobservable random variables or classical disturbance terms.

RESULTS AND DISCUSSION

Socio economic characteristics of the respondent's household

The study reveals that majority of the respondents of small farm group was illiterate representing about 28% followed by 31% and 13% of medium and large farmers, respectively. About 33% respondent (of large farm group) had primary level education while it was 31% for small and 20% for medium farm group (Table.1). It was also observed that about 44% respondents in large farm group had education at secondary level followed by 35% in medium and 25% in the small farm group. It was evident that 23% of the farmers in the medium farm group had education at higher secondary and above level followed by 10% of the respondent in large farm group and 6% in the small farm group. Average farm size was found to be 0.52 acre, 1.45 acre and 4.71 acre for small, medium and large farm category, respectively. Average family size was 6.33 (in no.) for small farm group followed by 5.35 and 4.25 for medium and large farm group, respectively. Average annual income of large farmers was higher than that of small and medium farmers in the study areas (Table.1).

Table 1. Socio economic characteristics of respondents' household

Indicator	Small farm	Medium farm	Large farm
Educational status			
Illiterate (%)	27.71	31.11	12,51
Primary (%)	31.33	20.15	33.33
Secondary level (%)	34.94	25.41	44.44
Higher secondary & above (%)	6.02	23.33	9.72
Farm size: (acre)	0.52	1.45	4.71
Family size: (no.)	6.33	5.35	4.25
Average Family Income (Tk)	294450.93	473175.35	730206.94

Source: Authors calculations based on field data

Profitability of early variety country bean cultivation

The following table (Table.2) shows the cost, return and benefit of country bean (early variety) production in the study areas. To determine the cost of home supplied inputs (such as family labor, for which no cash payment was actually made) the principle of opportunity cost was employed in this study. The study reveals that cost of human labor was the highest cost item followed by insecticide, fencing and stage making cost, cable, fertilizer, irrigation and so on. For bean production, human labor was the major component of the total cost which is much higher than those other costs, and the same results are found in several studies (Tun and Phyo, 2018). Interest on operating capital (IoC) was estimated at Tk 4123.44, Tk. 4677.41 and 6048.12 for small, medium and large farms, respectively. Land use cost was estimated for the cropping period covering around 4 months in the study areas. It is evident that the gross cost incurred by the large farmers was found to be the highest among the three categories of farmers. The benefit cost ratio (BCR) was found to be highest for large farmers (2.29) compared to that of medium (2.27) and small farmers (2.21). Since, BCR was greater than one for every category of farmers in country bean cultivation implying that country bean production was profitable in the study areas. which is similar to the findings of the study (Taslim et al., 2021).

Table 2. Cost and return of early variety country bean production in the study areas (Tk/ha)

Particulars	Category of farm		
	Small Farm	Medium Farm	Large Farm
Seed cost	2800	3080	3000
Human Labor Hired	69750	88000	145000
Family labor cost	78750	62500	6000
Fertilizer: TSP	3862.40	4112.00	4292.16
MoP	2654.40	2792.00	2890.42
DAP/Urea	6500.70	6801.40	6979.96
Insecticides	31737.77	31821.16	32245.37
Irrigation charge	5015.10	4832.77	5625.17
Cow dung	3171.08	2400.90	2663.60
Fence & stage	25557.10	25524.89	31676.23
Cable	13889.20	13167.91	15050.43
Interest on operating capital	4123.44	4677.41	6048.12
A. Total variable cost	247811.20	249718.40	261471.50
Land use cost	19000	19000	19000
B. Total fixed cost	19000	19000	19000
C. Gross Cost (A+B)	266811.2	268718.40	280471.50
D. Gross Return	589061.00	610385.0.	641275.0
E. Net Return (D-C)	39410.75	31276.25	29096.75
F. BCR	2.21	2.27	2.29

Authors calculation based on collected data

Technical efficiency analysis of country bean production

Technical efficiency refers to the ability of a farm to produce maximum possible output from a given set of inputs under certain production technology. Technical inefficiency refers to failure of a farm to operate on the production frontier. The estimate of the stochastic frontier shows the best practice i.e. efficient use of available technology.

Table 3. MLE of the parameters of C-D stochastic frontier production function

Variable	Parameters	Coefficient	Standard error	t-ratio
Constant	β_0	7.854***	1.189	6.603
Labor	β_1	0.336**	0.118	2.485
Seed	β_2	0.003	0.098	0.037
Insecticides/pesticides	β_3	-0.065**	0.032	-2.001
Irrigation	β_4	-0.124*	0.066	-1.882
DAP/Urea	β_5	-0.091	0.078	-1.165
TSP	β_6	0.121	0.114	1.057
MoP	β_7	-0.022	0.076	-0.299
Manure	β_8	0.213***	0.032	6.577
Fencing and Trail	β_9	0.114*	0.067	1.699
Cable	β_{10}	-0.0001	0.024	-0.007

Authors calculation based on the model

The results of the model (presented in the Table.3) revealed that the estimated value of the co-efficient of labor was positive (0.336) and significant at 5% level implying that on an average, country bean production would be increased by 0.336% if the farmers increases the human labor by 1%. The estimated value of the coefficient of manure was also positive (0.213) and significant at 1% level implying that if the farmer increases manure use by 1%, the production of country bean would be increased by 0.213%. The estimated value of the coefficient of fencing and trail was positive (0.114^{*}) and significant at 10% level implying that if the farmer increases the cost of fencing by 1%, the production of country bean would be increased by 0.114%. So, the farmers in the study areas may increase the use of human labor, manure and fencing to boost up country bean production with the existing technology. The estimated values of the co-efficient of seed and TSP were positive (0.003 and 0.121) respectively, but had no significant effect on country bean production. The findings of the study (Baucagu et al., 2013) showed that fertilizer application significantly has increased bean production and productivity variation was observed due to variations in fertilizer use by the farmers. The values of coefficient of DAP/urea, MoP and cable were negative (-0.091, -0.022 and -0.0001) respectively having no significant effect on country bean production. The values of the co-efficient of insecticide and irrigation were observed to be -0.065 and -0.124 and significant at 10% and 5% level, respectively implying that production of country bean would be decreased by 0.065%.and 0.124% if farmers increase the use of insecticides and irrigation by 1%. So, the farmers in the study areas should reduce the number of irrigation and doses of insecticide in order to use the resource efficiently in producing country bean. Irrigation is indispensable for vegetable production but a study (Ors et al., 2021) showed that excessive use of water reduced the yield.

Factors affecting technical inefficiency of country bean (early variety)

The sign of the 'δ' parameter in the inefficiency effect model was expected to be negative. The negative sign of the coefficients implied their inverse effect on technical inefficiency and direct effects on technical efficiency. The effect of some socioeconomic and demographic variables on technical efficiency included in technical inefficiency model (Table.4) is interpreted below.

Age: The co-efficient of age was positive (0.049) and highly significant (at 1% level) implying that the technical inefficiency increases as the age of farmers' increases. The older farmers were relatively inefficient than that of younger ones. The similar result was found in a study (Hafeez, *et al*., 2019) conducted in Bangladesh.

Education: The sign of the coefficient of education was positive (0.116) and significant at 5 percent level implying that technical inefficiency increases with increase of education level. It was unexpected but not surprising because one of the reasons may be that most of the educated farmers were found to have alternative income sources (service, business, etc.) and they were not very attentive to the farming practices. Another reason is that most of the educated farmers are village leaders and they were found to be busy with the problem of villagers and many of them were also engaged in politics. For that reasons they have devoted little time to their farming practices.

Farm size: The value of co-efficient of farm size in the inefficiency effect model was negative (-.002) and significant at 5% level implying that with the increase of farm size, the technical inefficiency decreases i.e the farm size of the farmers had the positive relationship with the technical efficiency.

Family size: The value of co-efficient of family size was positive (0.116) but insignificant implying that if family size increases the technical inefficiency decreases i.e technical efficiency increases. It indicates negative relationship with technical efficiency of bean production but had no significant impact on it.

Credit: The value of co-efficient of credit was negative (-0.174) but insignificant implying that the farmers who received credit can reduce technical inefficiency compared to the non- receiver of credit.

Table 4. Results of technical inefficiency effect model

Variable	Parameter	Coefficient	SE	t-ratio
Constant	δ_0	-4.223**	1.644	-2.568
Family size	δ_1	0.116	0.107	1.080
Farm size	δ_2	-0.002**	0.001	-2.547
Age	δ_3	0.049***	0.011	4.239
Education	δ_4	0.116**	0.042	2.713
Credit (Dummy: 1 if taken; 0, otherwise)	δ_5	-0.174	0.161	-1.081
Log likelihood value		60.18		
Mean technical efficiency		0.919		
Variance Parameter				
Sigma-squared	σ^2	0.180**	.063	2.875
Gamma	γ	0.987*	.006	164.01

Authors calculation based on the model used; Note: ***, ** and * indicate significant at 1%, 5% and 10% level, respectively

Dominance of inefficiency effect over random error can easily be visualized (Table 4) from the significant values of gamma (γ) (0.987). The γ parameter associated with the variances in the stochastic frontier is significant for country bean production which is similar to the findings of the study (by Zarin et al., 2015) on estimating wheat technical efficiency. It indicates that there were inefficiency effects in country bean production and the random component of the inefficiency effects made a significant contribution to the analysis of country bean production. The estimates of σ^2 (the ratio of the variance of farm specific technical efficiency to the total variance of output) was 0.180 and significant at 5% level. These suggest that the technical inefficiency effects were a momentous component to the total variability of the yield of early variety country bean.

Efficiency scores of country bean growers

The frequency distribution of the technical efficiency estimates of the farmers obtained from C-D stochastic frontiers for country bean production is shown in Table 5. It is evident that technical efficiency varied from 43.06 to 98.01 percent for the farmers. The mean technical efficiency of country bean farmers was 91.97% in the study areas. It is also evident that technical efficiency of country bean growers was distributed over a range from 40 to 100 and maximum farmers (73.33%) belonged to technical efficiency range from 91 to 100. The findings also showed that second major portion of the sampled farmers (20%) belonged to the technical efficiency range from 81 to 90 (Table 5).

Table 5. Frequency distribution of technical efficiency estimates

Efficiency level (%)	No. of farmers	Percentage
40-50	1	1.66
51-60	0.00	0.00
61-70	1	1.66
71-80	2	3.33
81-90	12	20.00
91-100	44	73.33
No. of farms		60
Minimum efficiency		43.06
Maximum efficiency		98.01
Standard deviation		4.7
Mean efficiency		91.97

Source: Author's estimation based on the C-D stochastic frontier model

The following figure shows the distribution of farmers according to technical efficiency

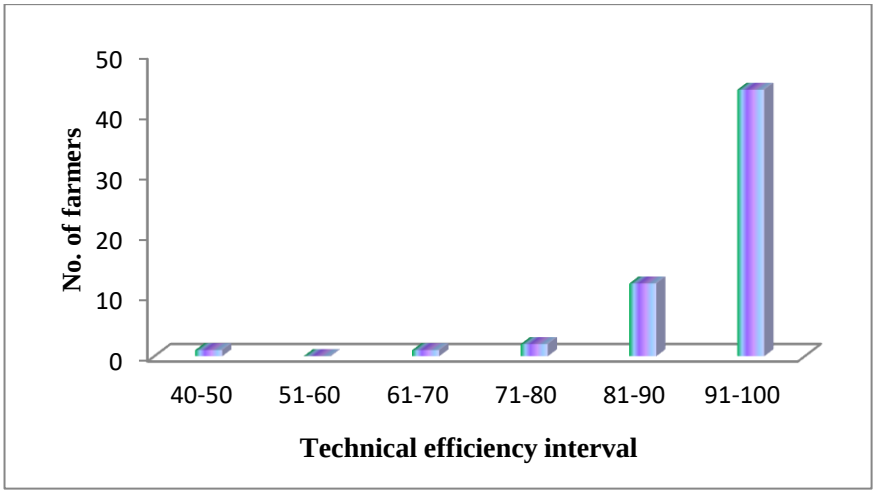

Figure 1. Frequency distribution of technical efficiency of country bean farmers

Constraints to country bean production as response by the farmers

The farmers were asked to describe the constraints what they faced in country bean cultivation in the study areas. These constraints were not uniform or identical and obviously varied from farmer to farmer and multiple answers were given by the respondents (Figure.2). The most important constraints in country bean cultivation faced by the farmers were identified as- incidence of pests and diseases (95%), lack of training on modern technology (91%), lack of extension services (90%), scarcity of human labor (89%), unavailability of credit (88%), lack of good quality seeds (79%), high price of other inputs (78%), low price of output (77%), transportation problems (75%), lack of operating capital (55%) and loss incurred due to theft of the product (29%).

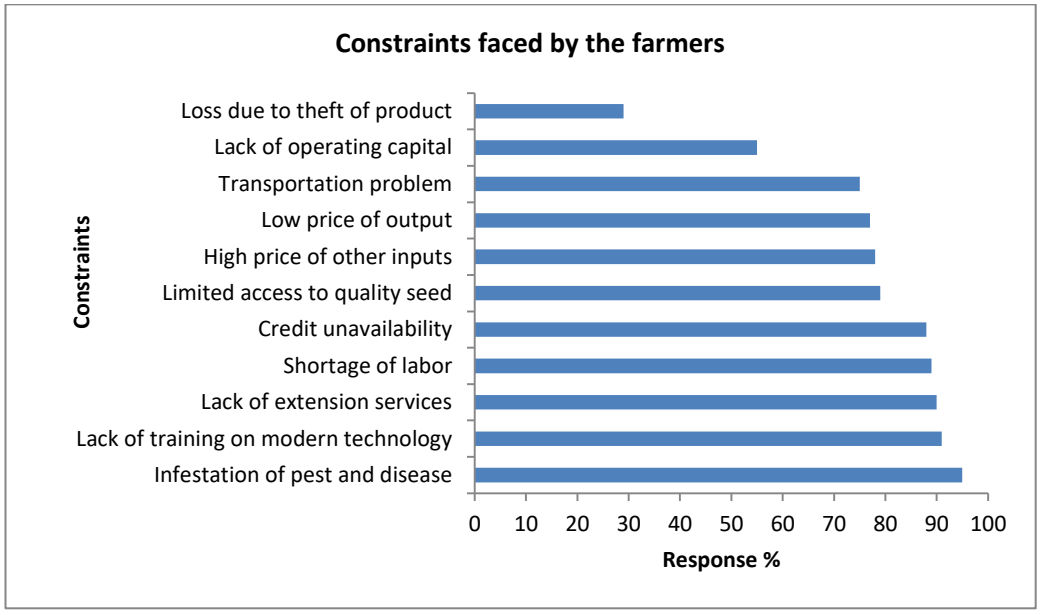

Figure 2. Constraints as response by the farmers in producing country bean (%)

CONCLUSION AND POLICY RECOMMENDATIONS

Based on the findings of the study it may be concluded that country bean (early variety) cultivation by the farmers in the study areas was profitable. Among the three categories of farmers large farmers earned higher gross return compared to small and medium farmers. It was also observed that labor, manure and fencing had significant positive influence on the production of country bean whereas insecticides, irrigation had negatively and significantly impacted the country bean production. The age and educational status had significant positive impact on the technical inefficiency of country bean production. Farm size had negative significant impact on inefficiency and farm credit had negative impact on inefficiency but not significant. The study revealed that the technical efficiency varied from 43.06% to 98.01%. Although the mean technical efficiency was 91.7% but majority of the farmers (73.33%) belonged to technical efficiency range from 91 to 100. and second major portion of the sampled farmers (20%) belonged to the technical efficiency range from 81 to 90 implying that there is an ample scope to increase the efficiency. Farmers should take decisions very cautiously for country bean cultivation to use existing resource in an efficient manner. Government should take appropriate measures to ensure fair price of product and marketing facilities for the farmers, adulteration in fertilizer and seed should be monitored and controlled strongly. NGOs, development organizations, extension and research institutions should provide adequate extension services and training on the use of modern technology. Country bean based cropping pattern should be developed for those areas, institutional credit should be provided to the farmers at an ease term and condition which may lead to expansion of early variety country bean farming in the country.

CONFLICT OF INTEREST

There is no conflict of research interest.

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